Field: Bioengineering/quantitative biology

Essays

Question 1 Essay - How did you choose your field and what are your primary expectations of your future career?

Every day I am amazed by the diversity and complexity of biological systems, and I am excited by the challenges of bioengineering and biology research. I love that scientists from any field can contribute to biology, and in turn biology can help advance these fields. For example, computer science has helped create the new field of computational biology, and the field of artificial intelligence has been inspired by neuroscience. I want to participate and contribute to the constantly evolving fields of biology and bioengineering through research and teaching.

I have worked [redacted] at Caltech since my second quarter of my freshman year. [redacted] I mainly study the genetics of heat shock induced gene expression, and I have cloned [redacted] During my characterization of [redacted] I used computational tools, such as JackHMMR, to study [redacted], and the results I obtained using such tools were critical to guiding future genetics and molecular biology experiments. From this experience I saw the power of computational biology to advance experimental biology, and I became interested in studying data analysis and mathematics to learn more about such methods. Additionally, coursework had made me realize that I was more interested in engineering and problem solving than conducting basic science research. One class that helped me develop these interests was CHE/BE 163: Frances Arnold's and Niles Pierce's course on biomolecular engineering. My favorite part of the course was when we used machine learning methods to predict properties of channelrhodopsin variants. This introduced me to machine learning and data mining, and I became fascinated by the power that these methods have to extract information from biological data. I thus immersed myself in the applied mathematics of data analysis and artificial intelligence through pursuing a minor in Information and Data Science (IDS). I challenged myself to obtain a thorough and broad technical education in mathematics and computer science, so that I could understand the underlying principles behind the most powerful data analysis and artificial intelligence methods and apply them to biological problems.

As I became more interested in bioengineering and data science, I decided to conduct research with [redacted] I was excited by his group's work on machine learning for *de novo* protein engineering. In the [redacted] I combined my knowledge of biology, mathematics and data science to work on developing and evaluating models that generate protein structures. I enjoyed the process of creating a generative model to best learn from the data and then exploring the model's capabilities and discoveries. I was fascinated while working in synthetic biology, for in trying to create *de novo* proteins we were forced to consider many basic, fundamental questions about what constitutes a "good" protein and whether or not nature's designs are optimal. My experience in the [redacted] cemented my desire to pursue a PhD in bioengineering, so I can continue working on solving challenging problems and exploring the limits of biology.

In addition to pursuing bioengineering research, I will work on making data science and mathematics more accessible to biologists. I have found that many biologists lack a strong understanding of data science, and thus are not aware of powerful methods they could use to more effectively learn from their data and guide their experiments. I want to develop a strong data science and mathematics education that is geared towards biologists, and to encourage students in fields that have been traditionally seen as less hard or quantitative to explore mathematics and data analysis. I hope that this will help empower biologists to take advantage of the rise of computing power that is facilitating the development of powerful data analysis methods.

In order to fulfill these goals as an engineer, scientist, teacher and mentor, I want to become a tenured professor at a research university. To achieve this goal, I will first pursue my PhD in bioengineering or biophysics. I am very excited for the opportunities I will have to teach, conduct research, and present my work in graduate school and beyond. Funding from the Hertz Foundation will help me achieve these goals through providing resources to support my training to become a strong scientist, mentor, and leader during graduate school.

Question 2: Proposed Field of Study

Question 2 Essay - How do your proposed field of study and career constitute an application of the physical sciences or engineering?

There are vast amounts of biological data available holding crucial information, but these patterns and knowledge remain obscure without appropriate analysis and inference methods. In graduate school and beyond, I want to develop computational methods to analyze and learn from biological data.

Broadly, I am interested in three types of problems: inference, prediction, and generation. First, I am interested in creating methods to infer information from biological data. Often, data comes in a form that is too obscure to be effectively processed by humans. Since scientists may never actually see the raw data themselves, it is important that they have a set of reliable tools that they can use to extract useful information from the raw data. For example, reads from a RNA seq experiment are processed to generate information about gene expression. However, data can be used for more than just inferring information about a given system: we can use data to make predictions about the properties of other systems. For example, in CHE/BE 163, I learned how to use machine learning methods to create models that learn from experimental data about properties of channelrhodopsin sequences to create a method for predicting properties of unseen variants. Engineers could then use this tool to predict properties of new sequences and decide which ones should be synthesized and experimentally characterized. In general, computational prediction is less costly and time consuming than experimental characterization, and thus these methods can be useful to scientists and engineers when making decisions and developing hypotheses. Finally, engineers can utilize data for generative applications. Generative modelling is a type of machine learning which seeks to learn probability distributions of data and then generate samples from that distribution. Generative modelling has been applied to *de novo* protein engineering to create new protein structures and sequences, which demonstrates that unsupervised machine learning models are able to approximate complex energy functions. One of the greatest challenges in bioengineering is that we are trying to engineer systems that we do not fully understand. Machine learning methods can make inferences from data without the need for a biophysical model. However, biological knowledge and intuition are instrumental for choosing and evaluating the quality of models. I am excited to combine my knowledge of biology and data science to create new computational tools and models to solve problems in biology and bioengineering.

Question 3: Choice of Graduate School

Question 3 Essay - What are the considerations involved in your choice of graduate school?

When choosing which graduate schools to apply to I first looked at the structure and culture of the school and program as a whole. I looked for institutions that are strong in mathematics, engineering, and biology, and then I looked for programs that emphasized quantitative biology, biophysics, or bioengineering. In addition to performing research, I want to continue with my technical education in mathematics and computer science. I thus want to be at an institution with strong faculty in these subjects, so I can take classes, learn from, and collaborate with leading researchers in those fields. While I do know that I want to work in bioengineering, there are many problems and subfields that I have not yet had the opportunity to explore. Therefore, I searched for programs which have rotations and give students time to work in different labs before choosing a research group. Finally, I searched for institutions with smart, passionate, open minded scientists from diverse backgrounds and perspectives. I believe that in order to understand biology we need to integrate techniques and knowledge from many fields including engineering, mathematics, physics, and computer science, and thus, I want to be part of an institution that encourages interdisciplinary collaboration.

After I found programs which appeared to meet the criterion described above, I searched for groups whose work is interesting to me. I looked for groups which are working on developing data analysis and machine learning methods to solve problems in biology and bioengineering. I loved working with [redacted] of Stanford on generative modelling for protein engineering, and I hope to have an opportunity to work in his group again. If I attended Stanford, I would also rotate with Prof. Russ Altman who is working on developing computational and informatics methods for medicine. I am interested in working with Prof. Sean Eddy at Harvard, because I have used Pfam for my research and I would like to contribute to this project. At MIT, I am excited by the work of Prof. Bruce Tidor, Prof. Christopher Voigt, and Prof. Mark Bathe. Finally, at UC Berkley I would like to work with Prof. Steven Brenner and Prof. Ian Holmes. However, I also have an open mind and I am excited to have the opportunity to work with scientists in fields I am less familiar with currently. I have had good interactions with Prof. KC Huang and Prof. Ariel Amir, who both work on biophysics and microbiology, and if I attend Stanford or Harvard I will try to set up rotations with them. One of the things I most excited for in graduate school is interacting with other scientists and trying new fields during rotation. While I know I could perform successful research at many institutions, Harvard, MIT, Stanford, UC Berkeley and UCSF stood out due to the amazing faculty, graduate students and opportunities I would have access to at those schools.

Hertz 2019-20
Interviewed

Question 1: Choice of Field and Future Expectations

How did you choose your field and what are your primary expectations of your future career? If you are currently in your second or later year of graduate school, you should make your case here for why receiving a Fellowship would result in exceptional leverage in the kind and quality of your graduate work, including your ability to pursue promising new ideas. Please understand before continuing this application, that such a case will have to be very strong to be considered further, and that new Hertz Fellowships are very rarely granted to students currently in their second year of graduate study or beyond.

My inspiration to study chemistry was solidified the first time I saw a crystal structure. There was something regular, mathematical, and structurally harmonious about three-dimensional periodic systems that fascinated and infatuated me. If not chemistry, I would have studied architecture. The chemical structure of the objects we see around us generate the inherent observable qualities that we take for granted, such as color, texture, and scent. However, the magnitude of this knowledge does not have to remain inconsequential. These invisible properties can also be harnessed to cure disease, power industry, and end wars.

I was fascinated that in adjusting chemical properties, man has the ability to tune and design new reactive and catalytic species. I can independently create structures with novel colors, magnetic properties, chemical reactivities and selectivities in an experiment, and justify the nature of these interactions using a pen and paper. More importantly, I can communicate to others why these discoveries are important, and equip them with fundamental knowledge better understand the world around them. I am a steward of the sciences, fostering discussion and community with those motivated to explore and employ the properties of our world that most take for granted. Resultant to these motivations, I am studying towards a Ph.D. in Inorganic Chemistry at the California Institute of Technology, creating multimetallic clusters modeling biological catalysts to revolutionize global energy industry.

Question 2: Proposed Field of Study

How do your proposed field of study and career constitute an application of the **physical** sciences or engineering?

My journey in research has been driven by practically applicable projects in energy use and efficiency, fueling my passion to study small molecule catalysis during my graduate degree.

Matriculating to my undergraduate institution, I was captivated that research allowed me to put scholarship into practice and see the fundamental principles from my courses take life. I was inspired to begin my first independent research project after enrolling in a general chemistry course taught by inorganic radiochemist Dr. Thomas Albrecht-Schmitt after he seamlessly integrated small narratives of his research aims and successes into class discussion. His group's research broadens the understanding of nuclear elements found in the lanthanide and actinide series, examining characteristic bonding trends for the *f*-series elements and critiquing use of lanthanide-series elements as actinide-series analogs. My individual project consisted of synthesizing lanthanide-series plumbite nanoclusters through hydrothermal synthesis, which yields distinct structural configurations based on the lanthanide element identity at the cluster's core. The motivation of this research is devising new methods to separate radioactive isotopes from bulk supplies of nuclear waste, in order to deplete the net volume of nuclear waste in storage. I was inspired by the extensive impact of this research, but over time realized that our independent projects contributed to *f*-block literature rather than reforming modern nuclear processes. Craving a new perspective, I applied to summer internships outside of my field of research to broaden my understand and challenge my interest in nuclear science.

The summer prior to my senior year, I accepted an offer to conduct research at the Massachusetts Institute of Technology through an interdisciplinary Research Experience for Undergraduates in the Center for Materials Science and Engineering. Unique to this program, our cohort was offered twenty-two research presentations and lab tours from MIT faculty conducting materials science research, allowing us to see the vast scope and applicability of materials science projects across disciplines. Motivated by his hands-on mentorship style, I chose to work under Dr. Yuriy Román-Leshkov in the Chemical Engineering department, creating transition metal carbide nanoparticles coated in an atomically thin platinum layer by reverse microemulsion-mediated synthesis. The synthesized nanoparticles catalyze hydrogen evolution reactions as effectively as pure platinum metal nanoparticles, but resist carbon monoxide poisoning to the catalyst. I explored adjustments to the existing nanoparticle architecture, and the resultant influence on the nanoparticles' catalytic properties. Through this program, I was involved in a project with strong ties to chemical industry that addressed immediate, pressing concerns in the future of petroleum technology; however, I felt that analyzing these problems from the perspective of an engineer overlooked the chemical fundamentals in favor of this practicality.

Resultant to my experiences, I have chosen to pursue a Ph.D. in Inorganic Chemistry. Bridging the synthetic inorganic chemistry experiences of my undergraduate research and catalysis research experiences from my summer internship, I have chosen to study novel inorganic clusters modeling catalysts found in biological systems for small molecule activation. The ultimate goal of this research is reducing energy barriers and increasing efficiency for global energy processes, including nitrogen fixation and carbon dioxide reduction, to promote global

energy independence from non-sustainable resources. In this research, I have certainty that my independent efforts will contribute to this cause over the duration of my degree and beyond.

With the support and network provided by the Hertz Foundation, I can fully exhaust my potential to act as a catalyst for change at the interface of academia and industry.

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Question 3: Choice of Graduate School

What are the considerations involved in your choice of graduate school?

I chose to attend the California Institute of Technology because the campus has a pervasive sense of humility and opportunity that I believed would best support my development as a research scientist and inspire the creativity of my research.

As a research scientist in-training, I thirsted for an environment that was saturated with students from all walks of life, and a community that was never short of intellectual potential. Attending my first day of classes at Caltech, it dawned on me that every person I encounter is uniquely exceptional. Each day I come to campus, I know that the student population around me is an extraordinarily hardworking and intelligent community, comprised of the world's future leaders in science across all disciplines. But beyond that, I am constantly mystified at the diversity of experience and breadth of culture all concentrated at one institution.

There is an inherently comfortable, collaborative culture that strongly ties the student community, in academics and beyond. When matriculating, graduate students are encouraged not to feel parameterized by their planned field of study and explore options of study outside of their own. Faculty office doors remain open, constantly encouraging communication and critical discussion with your instructors. Conferences and seminars are a daily activity, meaning that there is a constant stream of new encounters and networks being made available to you. Coursework strongly and genuinely encourages student collaboration on all assignments, with an emphasis placed on sharing knowledge interpersonally in addition to attending lecture.

Finally, I chose Caltech because this school is nothing like my home. As a first-generation college student, I am constantly reminded in my experience that my parents never had the opportunity to study at an institution of this caliber, or the flexibility to decide to move across the country to pursue their dream. I sought a graduate institution that would challenge my ideas and regularly push me outside of my comfort zone. Even outside of campus, there is so much inspiration in the heterogeneity of the Los Angeles area. Every time I walk outside between classes and see the mountains to the north of campus, I am reminded that attending this institution is the goal I had been working toward my entire life.

Question 4: Chronological Resume

Provide a concise resume, in chronological order, with dates, recapitulating significant periods of **technical and other creative activity** since high school graduation. Omit activities only distantly related to your professional development. Include workshops, summer schools, a general description of all courses of study pursued (e.g. "3 quarters of Differential Equations") and degrees expected or awarded (dates, institutions, fields). Separate your undergraduate activities from your graduate activities (if/as applicable) with a single dashed line.

FALL 2013
- Honors General Chemistry I with Laboratory (4 credits)
- Calculus I (4 credits)

SPRING 2014
- Honors General Chemistry II (3 credits)
- Honors-augmented Honors General Chemistry I – Conducted undergraduate research for academic credit as an alternative to lab coursework. (2 credits)
- General Physics A with Laboratory (5 credits)
- Calculus II (4 credits)

SUMMER 2014
- Calculus III (5 credits)
- General Physics B with Laboratory (5 credits)

FALL 2014
- Honors Organic Chemistry I (3 credits)
- Analytical Chemistry with Laboratory (4 credits) – Course on chemical instrumentation and analytical procedure.
- Directed Individual Study Research (1 credit) – Began undergraduate research project under Dr. Thomas Albrecht-Schmitt.
- General Genetics (3 credits) – Enrolled in course to complete Biology minor, coupled with AP Biology credit.
- Intro to Scientific Computing – Enrolled in a course applying Java coding to problems in math and science, out of leisure and curiosity.
- National Aeronautics and Space Administration Virtual Internship – Began virtual internship providing technical support to the Office of Human Capital Management.

SPRING 2015
- Organic Chemistry II (3 credits)
- Chemistry of Materials (3 credits) – Elective upper-division and graduate mixed course, which covers the fundamentals of experimental chemistry methods.
- Honors Directed Individual Study Research (3 credits) – Continuing research project.
- Ordinary Differential Equations (3 credits) – Enrolled in course out of interest.
- Programming I (3 credits) – Enrolled in course out of interest.

SUMMER 2015
- General Biochemistry I (3 credits) – Course completed for degree certification.

- Organic Chemistry Lab (3 credits)

FALL 2015
- Physical Chemistry I with Laboratory (4 credits) – Thermodynamics for chemists.
- Honors Work (2 credits) – Continuing undergraduate research project.
- Symbolic and Numerical Computations (3 credits) – Course covers mathematical derivations of computational algorithms. Learned and applied Matlab.

SPRING 2016
- Physical Chemistry II with Laboratory (5 credits) – Quantum mechanics for chemists.
- Advanced Analytical Chemistry (3 credits) – Course covering chemical instrumentation and data analysis.
- Honors Work (3 credits) – Continuing undergraduate research project.
- Algorithms for Science Applications I – Matlab course focused on algorithms with applications in science and engineering.

SUMMER 2016
Research Experience for Undergraduates – MIT Center for Materials Science and Engineering

FALL 2016
- Quantum Mechanics (Graduate, 3 credits) – Enrolled in graduate course out of personal interest.
- Inorganic Chemistry (3 credits) – Course covers the fundamentals of metal-based chemistry.
- Advanced Analytical Chemistry Lab (1 credit) – Hardest course of my degree. Laboratory instrumentation course with high standards of performance. Received grade in the course.
- Data Mining (Graduate, 3 credits) – Fundamentals and practical applications of machine learning.
- Honors Work (3 credits) – Continuing undergraduate research project.

Spring 2017
- Inorganic Chemistry Laboratory (1 credit) – Laboratory course covering metal chemistry,
- Principles of Inorganic Chemistry (Graduate, 3 credits) – Course continues covering the fundamentals of metal-based chemistry.
- Bio-Nanomaterials (Graduate, 3 credits) – Course covers physical chemistry analysis for polymeric and nanoparticle systems.

FALL 2017
- Structure Determination by X-Ray Crystallography (9 units)
- Inorganic Chemistry (9 units)
- Introduction to Electrochemistry (9 units)

Academic Honors

In the space provided below, list, in chronological order, academic honors and distinctions which you have received and the time or time-interval of receipt. Separate your undergraduate from your graduate awards (if/as applicable) with a single dashed line (Include title, reason for award, and where/when received). Especially significant awards received in high school can also be included. Use no more than one line per award whenever possible (what, where/when received). *You may use more than the allotted space for your response, and any additional text will be included in your application.*

Florida State University Freshman Scholarship – Awarded $9600 Florida State University institutional scholarship based on high school merit (August 2013).

* Phi Eta Sigma Honor Society membership - Awarded membership to national honor society (March 2014).

* Phi Beta Kappa Honor Society – Awarded membership to national honor society as an academic junior with 3.9 GPA (October 2014).

Russell H. and Dorothy P. Johnsen Scholarship – Awarded $2000 Florida State University Chemistry departmental scholarship, selected on academic merit and research experience (April 2015).

Goldwater Scholarship – Selected Florida State University Goldwater scholarship nominee based on research proposal and personal statement (January 2016).

Scholarship Award – Garnet and Gold Key Leadership Honorary – Nominated and selected by peer leaders for academic accomplishment (March 2016).

The Charles A. and Louise I. Brautlecht Scholarship in Chemistry – Awarded $2000 Florida State University Chemistry Departmental scholarship, selected on academic merit and research experience (April 2016).

*Department of Energy Integrated University Program Scholarship Awarded $7500 for undergraduate research in nuclear science. Award selected based on research merit, reference letters, and personal statement. (FY 2015-2016).

* MIT Center for Materials Science and Engineering Research Experience for Undergraduates – One of twelve students admitted to competitive interdisciplinary summer research internship. Study in nanoparticle synthesis and catalysts for hydrogen evolution reactions under Dr. Yuriy Roman- Leshkov (Summer 2016).

*Department of Energy Integrated University Program Scholarship- Awarded $7500 for undergraduate research in nuclear science. Award selected based on research merit, reference letters, and personal statement. (FY 2016-2017).

Institutional Research Fellowship - California Institute of Technology Department of Chemistry and Chemical Engineering – Funding to support research endeavors in the first academic year of graduate study (2017-2018)

Fellowships, Scholarships, etc.

Florida State University Freshman Scholarship – Awarded $9600 Florida State University institutional scholarship based on high school merit (August 2013).
* Phi Eta Sigma Honor Society membership - Awarded membership to national honor society (March 2014).
Florida State University Student Government: Undergraduate Studies Seat Sixteen – Elected student leader in Florida State University Student Government Association, representing predivisional undergraduate students (March 2014).
Seminole Torchbearers Recognition – Leadership recognition conferred by the Florida State University Division of Student Affairs (October 2014).
Garnet and Gold Key Leadership Honorary – Awarded membership to Florida State University's oldest honor society, with tenants of leadership, service, spirit, and scholarship (October 2014).
* Phi Beta Kappa Honor Society – Awarded membership to national honor society as an academic junior with 3.9 GPA (October 2014).
Florida State University Student Government: Student Senator of the Year – Nominated and elected award by over sixty cohort student-leaders in the Florida State University Student Senate (March 2015).
National Aeronautics and Space Administration – Virtual Student Foreign Service – Virtual internship with the NASA Office of Human Capital Management, coordinating internal and public virtual meetings with NASA staff and leadership (September 2014 – April 2015).
Russell H. and Dorothy P. Johnsen Scholarship – Awarded $2000 Florida State University Chemistry departmental scholarship, selected on academic merit and research experience (April 2015).
College Leadership Florida, Class XVII – Membership in Leadership Florida, a statewide network and community of leaders working for a better Florida (August 2015).
Goldwater Scholarship – Selected Florida State University Goldwater scholarship nominee based on research proposal and personal statement (January 2016).
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Tutorial Assistant – Florida State University Center for Retention and Academic Enhancement - Mathematics and science tutor for students enrolled in the FSU CARE Program, which provides transition, engagement, and academic support services for traditionally underrepresented and

disadvantaged populations at Florida State University (Summer 2015- Spring 2017).
Undergraduate Teaching Assistant for Organic II Laboratory (CHM 2211L) – Florida State University Department of Chemistry - Teaching assistant for a three credit-hour upper-division course. Instruct, grade, and advise for one section containing sixteen students (Fall 2016, Spring 2017).

Institutional Research Fellowship - California Institute of Technology Department of Chemistry and Chemical Engineering – Funding to support research endeavors in the first academic year of graduate study (2017-2018).

Previous Research

B.S. Researches Pursued
3
B.S. Researches Documented
3
B.S. Researches Submitted to Refereed Publications
1

Grad. Researches Pursued
1
Grad. Researches Documented
0
Grad. Researches Submitted to Refereed Publications
0

Previous Research
1) "Quantification of Mn2+ in a Mn-doped Dimethylammonium Zinc Formate Framework." (January 2014 – April 2014)

ORAL PRESENTATION:

Barth, A. T.; Abhyankar, N; Dalal, N. S., (2014, April). Quantification of Mn2+ in a Mn-doped Dimethylammonium Zinc Formate Framework. Delivered at Florida State University, CHM 1051L Course Recitation.

POSTER PRESENTATION:

Barth, A. T.; Abhyankar, N; Dalal, N. S. "Quantification of Mn2+ in a Mn-doped Dimethylammonium Zinc Formate Framework." April 2014. Florida State University, Department of Chemistry and Biochemistry, CHM 1051L Honors General Chemistry II Laboratory Research Poster Session, Tallahassee, Florida.

2) "Hydrothermal Synthesis of Lanthanide Series Plumbites." (May 2014 – December 2016)

PUBLICATION

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Beatrice, M. T.; Silver, M. A.; Cary, S. K.; Eaton, T. M.; Albrecht-Schmitt, T. E., "Hexanuclear and Pentanuclear Lanthanide Plumbite Nanoclusters." (In Preparation)

ORAL PRESENTATIONS:

Barth, A. T.; Stritzinger, J. T.; Albrecht-Schmitt, T. E., (2015, November). Synthesis and Study of Lanthanide Series Plumbites. Delivered at Florida State University, American Chemical Society General Body Meeting.

Barth, A. T.; Stritzinger, J. T.; Albrecht-Schmitt, T. E., (2015, March). Synthesis and Study of Lanthanide Series Plumbites. Delivered at Florida State University, Undergraduate Research Showcase.

POSTER PRESENTATIONS:

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." January 2017. Harvard University, National Collegiate Research Conference, Cambridge, Massachusetts.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." March 2016. Florida State University, FSU Center for Research and Creative Endeavors, FSU Undergraduate Research Symposium 2016, Tampa, Florida.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." February 2016. University of Tampa, Florida Undergraduate Research Conference 2016, Tampa, Florida.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." May 2015. Florida State University, Department of Chemistry and Biochemistry, 2015 North American Solid State Chemistry Conference, Tallahassee, Florida.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." May 2015. American Chemical Society Florida Section, Florida Annual Meeting and Exposition, Tampa, Florida.

3) "Transition Metal Carbide Nanoparticles Coated with Noble Metal Monlayers for CO-Tolerant Catalysis." (June 2016 – August 2017)

POSTER PRESENTATION:

Barth, A. T.; Milina, M.; Román-Leshkov, Y. "Transition Metal Carbide Nanoparticles Coated with Noble Metal Monlayers for CO-Tolerant Catalysis." August 2016. Massachusetts Institute of Technology, Center for Materials Science and Engineering, The CMSE/MPC Summer Research Internship Program Poster Session, Cambridge, Massachusetts.

4) “Modeling the Nitrogenase FeMo Cofactor with Tunable Multimetallic Clusters.” (October 2017 to present)

***** IMPORTANT*****
Finally, choose one or two projects that best exemplify your own creativity and discuss in more detail what you personally contributed to them.

Note that compelling example(s) of personal creativity are a very important factor in our selection process. Please highlight what makes your personal contributions stand out, and use the first person wherever appropriate. Specific evidence of your personal creativity is more important to us than what your research group did as a whole, unless you contributed centrally to its leadership.

Please submit copies of your most significant scientific publications/reports using the upload button on the Supplemental & Other Information page of this application.

The research experience that inspired and broadened my perspective the most was my summer experience interning in a chemical engineering laboratory. In retrospect, this experience was a summer of reciprocal gain, as I intellectually challenged the protocol and methodologies assumed by my research group, and they responded in kind. From a chemistry perspective, conducting research means being astutely observant of the slightest nuances in a reaction that could completely throw your equilibrium and render your experiment useless. Exploratory research is usually performed conservatively on the milligram scale, and products are handled carefully as through valuable at all times. In stark contrast, the chemical engineering research in my laboratory was a research of haphazard and extremes relative to my previous experiences. Exploratory research was conducted on a gram scale or in huge multi-liter apparatuses. Solvents were purchased in bulk and consumed in a week, and most days were spend listening to the harsh clanging of two wrenches together as gas tanks were exchanged.

During the summer, I was enlisted to work on a ninety-step reverse microemulsion-mediated synthesis project. In my project, I frequently realized inefficiencies in the procedure, and proposed methods of reforming and expediting the research while preserving integrity of the data. After brainstorming project ideas with another graduate student, I suggested that he change his experiment parameters to attain the thermodynamic versus kinetic intermediate, which entirely shifted the direction of his thinking while approaching the problem. Additionally, I ran electrochemical experiments for the first time as a method of evaluating the effectiveness of researched catalysts; after weeks of tribulation, I troubleshoot evaluated the instrumentation and independently reconfigured the setup to remedy the circuitry issues. Through this experience, I learned to appreciate the differing experimental lens of my cohort, and through mutual discussion of our differing perspectives, we can both intellectually benefit.

Were you a Goldwater Scholar or Nominee? Nominee

Personal Essay
This page is to be used for submitting a personal essay or for pasting in an essay that is TEXT only. Include here information about your favored extracurricular and leisure time activities since your graduation from high school. **You may use more than the allotted space for your response, and any additional text will be included in your application.**

During my undergraduate degree, I was intimately involved in the operation and management of a Student Government political party. Titled "The Ignite Party," and symbolized by a simple flame on a paprika-red backdrop, I was introduced to this organization early through my involvement in a freshman leadership program at Florida State University. The political party system enabled students to band together as a united front during Student Government elections in the Fall and Spring terms, selecting qualified candidates to run for student-leadership office, and bear the elected responsibility of allocating and spending the $13.7 million university Activities and Services Fee budget. I sought a sense of community when matriculating to a school of over 40,000, and found many of the most distinguished student-leaders shared this same affiliation.

My early involvement in Student Government led to holding an executive board position within the Ignite Party and committee leadership position in Student Senate by my sophomore year. My involvement and leadership soon involved controversy when articles for impeachment were filed against the elected Student Body President during my sophomore year, and I was responsible for the judicial committee to investigate the claims and determine his culpability. I was thorough in investigating all evidence under record and respectfully refused all discussion off record until the process was complete. Despite the contention this period brought about, I constantly took a seat at the table, interjected, and mediated discussion when tensions arose.

In the following Spring, a conflicting faction of The Ignite Party developed into an opposing political party and challenged our election slate. Campaigning activities followed strict guidelines to maintain public decorum and noninterference with academia, and if a violation was reported, student party leaders were responsible for litigating their case before third-year law students to avoid monetary fines or party disqualification. During this process, I was constantly requested as the primary litigator on behalf of my party, and if busy, I framed the argument against each violation and coached my cohort leaders in the unpacking and negation of each claim made against us. I frequently argued cases submitted by law students and won as an undergraduate sophomore with no prior oratory or debate experience.

My favorite part about involvement in this organization was the opportunity to recognize potential student leaders in their freshman year, mentor and inspire these students, and see how they develop throughout their undergraduate career and beyond. Although my intentions with this party were always in good faith, I experienced moral difficulties as the party began to develop into something I could no longer recognize or believe in. The most difficult decision of my undergraduate involvement was making the announcement to dissociate from this organization and abandon many of my invested experiences in the process. In retrospect, my impassioned involvement with this organization helped me realize the boundlessness of my capability, shaping my self-confidence and developing leadership skills through application. These experiences challenged my ability to improvise in the face of adversity, creatively tackle and solve problems, and respectfully communicate disagreement and controversy with others. These qualities are congruent with my personality and passions, and because of these experiences, I have grown into a much more spontaneous, intentional, and imaginative scientist and researcher.

2017 Winner

In the spaces below (i.e., in approximately 300 words), please provide concise responses to each of the following questions.

1) How did you choose your field and what are your primary expectations of your future career? **If you are currently in your second or later year of graduate school**, you should make your case here for why receiving a Fellowship would result in exceptional leverage in the kind and quality of your graduate work, including your ability to pursue promising new ideas. Please understand before continuing this application, that such a case will have to be very strong to be considered further, and that new Hertz Fellowships are very rarely granted to students currently in their second year of graduate study or beyond.

As a Princeton undergraduate I studied a wide variety of academic disciplines in order to understand the world, ranging from music to math and elixirs to ethnographies. This breadth of exploration provided me with the foundation to make connections between seemingly disparate fields, empowering me to apply the tools from one discipline to the problems of another. Through this investigation, I discovered that my intellectual passion does not lie in any one field, but is instead directed towards an object of study: the coupled physical, chemical, and biological evolution of Earth.

Within geoscience, the tool I have found most compelling is the use of isotope ratios in natural materials such as rocks, ice cores, cave deposits, and organic molecules to reconstruct the biogeochemical cycles of past environments. Isotope ratios are powerful tools because they record the signatures of planetary processes without influencing the active dynamics. Isotope biogeochemistry and paleoclimate sit at the intersection of the geologic record with modern ecology, combining two complex fields to tell an engrossing story of the evolution of life and climate on our planet. I will use isotope ratios to read Earth's biography, a story in equal parts elegant and confounding, but always utterly engaging.

While Earth's climate has changed in the past, the rate of modern global warming poses an unprecedented risk to the health and safety of the United States and its international partners, both immediately and over the coming decades. My research using isotope ratios to understand Earth's ancient biogeochemical cycles is critical for predicting and mitigating the impacts of modern carbon emissions. Without a process-based understanding of how the interconnected cycles of carbon, oxygen, sulfur, and nitrogen have altered climate in the past, our society cannot pass effective climate laws or design infrastructure for the future. However, while science typically moves forward in slow steps, preventing catastrophic climate change will require rapid leaps built around bold new ideas. The Hertz fellowship will provide an unparalleled opportunity to tackle the most important questions of our time outside of the financial constraints imposed by an advisor's grant, to pursue without monetary limitation the non-traditional ideas required to prevent environmental disaster. The freedom to pursue new research without limits requires committing fully to the science of combating modern climate change, and I will be honored to take on this responsibility.

In the near-term, I will measure isotope ratios, study the history of climate on our planet, and work with local schools to teach students about global warming and the geosciences.

In the long-term, I aspire to contribute to our collective knowledge of Earth history in order to help society respond to the challenges of modern climate change. I am working to become a principal investigator at a major research university, where I will collaborate with graduate students and scientists across disciplines to further our understanding of Earth's environments and to effectively communicate that knowledge to policy makers.

2) How do your proposed field of study and career constitute an application of the **physical** sciences or engineering? *You may use more than the allotted space for your response, and any additional text will be included in your application. However, when you print this page, only the text that appears in the text box will print.*

Anthropogenic emissions are altering Earth's environments, impacting components of the climate system such as ocean circulation, atmospheric chemistry, and terrestrial nutrient availability. While such changes can be mutually dependent, geologic evidence from Earth's history records how discrete elements of climate have shifted in the past. Reading these historical archives to understand the behavior of Earth's climate system is critical for informing our response to the threats of both modern climate change and the attendant potential of a new geopolitical reality.

Stable isotope analysis is an essential technique for interpreting the geologic record. Because each element of the periodic table responds uniquely to different environmental conditions and processes, comparing isotope ratios in samples across environments and historical eras illuminates the strength, relative timing, and relationships between the components of the planet's climate. For example, the isotopic composition of oxygen in ice cores reveals that atmospheric chemistry has oscillated between glacial and interglacial states over the past 2.5 million years, while nitrogen isotope ratios from phytoplankton microfossils indicate that much of the perturbation resulted from changes in ocean stratification.

Interpreting isotopic signals to infer the feedbacks between processes requires synthesizing and applying knowledge from across the basic physical sciences. Understanding the isotopic ratios of sulfur in ancient rocks may entail an evolutionary treatment of microbial metabolisms, thermodynamic considerations of post-formational alteration, or physically modeling how water is transported to submarine hydrothermal vents. By applying such concepts from biology, chemistry, and physics to the study of the ancient Earth, we can deconvolve climatic feedbacks and begin responding effectively to anthropogenic emissions. Studying the sulfur isotope ratios in ancient rocks can clarify the coupling of the sulfur, oxygen, and carbon cycles, providing valuable insight into how modern carbon emissions may impact elements of the climate such as hurricane intensity, sea level, and the pH of rainwater. I am excited to continue studying the planet's history, for the isotopic records from Earth's past contain the solutions for its future.

3) What are the considerations involved in your choice of graduate school? *You may use more than the allotted space for your response, and any additional text will be included in your application.*

While at Princeton, I was fortunate to have the opportunity to conduct research with several excellent scientific mentors who invested their time and hard-won resources into my growth as a scholar. Through spirited discussion and disagreement, I learned to make robust measurements, analyze data, and write publications. When applying to graduate school, I appreciated and heeded the advice of my advisors, who stressed attending a university with the instrumentation, faculty, and students required to address fundamental questions about our planet. After much deliberation, I choose to pursue my PhD in Geochemistry at the California Institute of Technology.

Foremost, I was drawn to Caltech's extraordinary commitment to exploring the frontiers of isotope geochemistry. There is no other institution that invests the same resources into developing experimental methods and acquiring mass spectrometers. The quintessential example of this commitment is recent research completed by Professor John Eiler and his students into the abundance of molecules with two rare isotopes. The presence of such molecules can be used to estimate the temperature at which the molecule formed, with applications ranging from estimating the internal temperature of a dinosaur to the rate of global ocean circulation during ice ages.

Second, I choose to attend the California Institute of Technology due to the strength of its faculty. Caltech boasts a large and interdisciplinary group of scientists utilizing stable and radioactive isotope ratios to explore diverse topics, from an extinct manganese-oxidizing microbial metabolism to the physical dynamics of planetary formation. The Division of Geological and Planetary Sciences boasts more professors than almost any comparable university, with at least five researchers who could feasibly advise my doctoral thesis. Moreover, the Caltech faculty encourages an overarching culture of collaboration among research groups; many laboratories have the same door key, resources are shared, and students will frequently publish articles supported by multiple advisors.

Third, I was attracted to the rigor of Caltech's academic program. In addition to a heavy course load, students conduct two research projects during their first year and present them at the qualifying examination. I want to become a world-class scientist and I am confident that this demanding course of study will help me get there.

Lastly, I choose to attend Caltech because I was excited to join a creative and intensely intellectual student body dedicated to original research. I enjoy exploring concepts and developing novel connections, so I wanted to attend a program where my peers would be enthusiastic about discussing research. Indeed, some of my best thinking has arisen from debating ideas with fellow students. For example, my recent work constructing a model of the glacial Southern Ocean has benefited immensely from continued debate with a current graduate student at Princeton. Our discourse has improved the mathematical formalism I use to represent isotopic discrimination, and this discussion is already continuing with students at Caltech.

Finally, choose one or two projects that best exemplify your own creativity and discuss in more detail what you personally contributed to them. Note that compelling example(s) of personal creativity are a very important factor in our selection process. Please highlight what makes your personal contributions stand out, and use the first person wherever appropriate. Specific evidence of your personal creativity is more important to us than what your research group did as a whole, unless you contributed centrally to its leadership. Please submit copies of your most significant scientific publications/reports using the upload capability on Page 13.

For the last two years, I have worked closely with Professor Daniel Sigman to study whether and how seasonal dynamics in the ocean surrounding Antarctica should influence paleoceanographic reconstructions (research experiences 5 and 8 listed above). In the experimental component of this project, I measured the nitrogen (N) and oxygen (O) isotope ratios of seawater nitrate and nitrite. Culture studies have shown that the N and O isotope ratios of nitrate increase in tandem as nitrate is consumed, which was the observation I recovered when looking at the combined isotopes of nitrate and nitrite. However, when I performed an analysis of nitrate-only, I measured an imbalance in the rate of increase of N and O isotope ratios. Taken together, these two observations were inconsistent with prior findings and suggested a novel process in the marine N cycle. While the identification of this discrepancy occurred as a result of following established experimental protocols, the subsequent analysis of the data exemplifies my personal creativity.

First, I used a Monte Carlo simulation to calculate the value and uncertainty of the N isotope ratio in nitrite, showing that the divergence between nitrate+nitrite and nitrate-only data was constrained to the ocean mixed-layer. While the calculation of nitrite isotopes is not novel, the use of a Monte Carlo simulation to avoid covariance complications was an original contribution to our laboratory.

Professor Sigman and I then developed the hypothesis that my observations resulted from the reversibility of a biochemical reaction. To test this idea, we required a way to quantify and relate the extent of reaction reversibility to ocean parameters, such as temperature and salinity. This hypothesis testing would commonly be conducted as its own experiment, with additional time, resources, and samples. My second major creative contribution was to develop a numerical method for quantifying the intensity of N isotope exchange between nitrate and nitrite using only the N and O isotope ratios I had already measured. My solution was to relate the extent of reaction reversibility to the difference between the apparent values of two N isotope effects, a derived parameter that describes the degree of isotopic discrimination. My expression of exchange intensity was very well correlated with the depth of the ocean mixed-layer, providing quantitative support for our hypothesis that an enzyme-catalyzed equilibration process could explain the measured isotope discrepancy.

Finally, on Professor Sigman's suggestion, I reviewed published data for prior evidence of the enzyme-catalyzed interconversion of nitrate and nitrite. In particular, I focused on a recent dataset that argued for a relationship between the strength of the isotope effect of nitrate assimilation and the depth of the mixed layer. When I account for the bias in N isotope ratios that occurs due to the interconversion process, the relevant isotope effect has much lower variability than previously suggested. This contribution stands out because the observation derives from existing data and will have important ramifications for our interpretation of paleoceanographic N isotope ratios and the dynamics governing glacial-interglacial cycles.

8) This page (Page 12) is to be used for submitting a personal essay or for pasting in an essay that is TEXT only. Include here information about your favored extracurricular and leisure time activities since your graduation from high school. **You may use more than the allotted space for your response, and any additional text will be included in your application. However, when you print this page, only the text that appears in the text box will print.**
From website: Question*: What is the Hertz Foundation looking for in the personal essay?*
Answer: *The personal essay is your choice on the topic suggested—it is intentionally open-ended.*

Growing up in the woods of Garrison, NY, an upstate town in the Hudson River Valley, I became an avid hiker, conservationist, and vegetarian. I love being outside, whether I'm backpacking, cycling, or simply walking, and I try to spend my leisure time engaged in outdoor activities. One of my favorite parts of studying Earth Science is thus that I get to be outside as part of my education. However, for the past few years I have spent most of my time thinking about natural systems from theoretical and laboratory-based perspectives, rather than outside experiencing the world. These experimental and mathematical approaches, while very powerful, can separate me from the actual object of study; it is possible to fall into a space between what is mathematically possible and what is outside the window. To me, the outdoors is the full solution to the research; it represents theory in experiential form, a way to walk through equations and physically interact with concepts. I love what I study and I love to be outside because they are two complementary sides, the theoretical and the real. When outdoors, I am reminded how complex and powerful reality actually is.

As a trip leader for Princeton's wilderness organization, Outdoor Action, I completed training in both sustainable camping techniques and wilderness rescue medicine, making me very comfortable traveling and working in remote environments. As part of the program, I enjoyed guiding students on six-day wilderness outings. In addition to providing the opportunity to share my passion for nature and conservation with other students, collaborating with my peers taught me a lot about leadership. Meeting the demands of outdoor challenges like rattlesnakes and torrential rains forced me to become flexible and creative, confident but adaptive to evolving situations. I learned to think clearly in stressful scenarios, to work with my fellow trip leaders, and to lead boldly when necessary. However, I also learned when to step back and follow, particularly when facilitating the development of skills in others. These experiences are widely transferrable to my work as a scientist and educator, where I am frequently faced with uncertain and surprising situations. Fixing a clogged needle on a mass spectrometer requires the same quick thinking and dexterity as responding to an allergic reaction, and resolving a confusing protocol has many parallels with following a poorly marked trail.

While hiking near home and school is terrific, I also relish the opportunity to be outdoors in environments overseas. Exploring ecosystems around the world has deepened my commitment to addressing climate change through my research by revealing the fragility of many environments and the communities that depend upon them. The forces that shape our planet's surface collude to generate enormous environmental diversity that impacts climate and humanity. Visiting a range of ecosystems provides a critical context for both interpreting the isotopic ratios in natural materials and responding to modern carbon emissions. This year I had the extraordinary opportunity to visit all seven continents. While my research interests took me to South Africa, Antarctica, Japan, and Iceland, my personal sense of adventure took me backpacking across Europe, New Zealand, Peru, and Thailand. In canyons, mountain, and beaches, I learned firsthand about sediment transport, hydrothermal alteration, and karst formations. Moreover, traveling to different environments and ecosystems has allowed me to interact with students from different cultures. This exchange provided the rare opportunity to learn to view the world through different lenses, to recognize and move away from the biases with which I was raised.

Although I have had incredible opportunities to explore the outdoors over the past few years, both during my free time and in my studies, I have come to appreciate just how little I actually know. While I am beginning to scratch the surface of Earth's history, I aspire to delve deeply and share that knowledge with students and policy makers in order to prevent environmental catastrophe. There is a lot left to learn and to do, and I think that is extremely exciting.

2017

Question 1: Choice of Field and Future Expectations

How did you choose your field and what are your primary expectations of your future career? If you are currently in your second or later year of graduate school, you should make your case here for why receiving a Fellowship would result in exceptional leverage in the kind and quality of your graduate work, including your ability to pursue promising new ideas. Please understand before continuing this application, that such a case will have to be very strong to be considered further, and that new Hertz Fellowships are very rarely granted to students currently in their second year of graduate study or beyond.

My inspiration to study chemistry was solidified the first time I saw a crystal structure. There was something regular, mathematical, and structurally harmonious about three-dimensional periodic systems that fascinated and infatuated me. If not chemistry, I would have studied architecture. The chemical structure of the objects we see around us generate the inherent observable qualities that we take for granted, such as color, texture, and scent. However, the magnitude of this knowledge does not have to remain inconsequential. These invisible properties can also be harnessed to cure disease, power industry, and end wars.

I was fascinated that in adjusting chemical properties, man has the ability to tune and design new reactive and catalytic species. I can independently create structures with novel colors, magnetic properties, chemical reactivities and selectivities in an experiment, and justify the nature of these interactions using a pen and paper. More importantly, I can communicate to others why these discoveries are important, and equip them with fundamental knowledge better understand the world around them. I am a steward of the sciences, fostering discussion and community with those motivated to explore and employ the properties of our world that most take for granted. Resultant to these motivations, I am studying towards a Ph.D. in Inorganic Chemistry at the California Institute of Technology, creating multimetallic clusters modeling biological catalysts to revolutionize global energy industry.

Question 2: Proposed Field of Study

How do your proposed field of study and career constitute an <u>application</u> of the **physical** sciences or engineering?

My journey in research has been driven by practically applicable projects in energy use and efficiency, fueling my passion to study small molecule catalysis during my graduate degree.

Matriculating to my undergraduate institution, I was captivated that research allowed me to put scholarship into practice and see the fundamental principles from my courses take life. I was inspired to begin my first independent research project after enrolling in a general chemistry course taught by inorganic radiochemist Dr. Thomas Albrecht-Schmitt after he seamlessly integrated small narratives of his research aims and successes into class discussion. His group's research broadens the understanding of nuclear elements found in the lanthanide and actinide series, examining characteristic bonding trends for the *f*-series elements and critiquing use of lanthanide-series elements as actinide-series analogs. My individual project consisted of synthesizing lanthanide-series plumbite nanoclusters through hydrothermal synthesis, which yields distinct structural configurations based on the lanthanide element identity at the cluster's core. The motivation of this research is devising new methods to separate radioactive isotopes from bulk supplies of nuclear waste, in order to deplete the net volume of nuclear waste in storage. I was inspired by the extensive impact of this research, but over time realized that our independent projects contributed to *f*-block literature rather than reforming modern nuclear processes. Craving a new perspective, I applied to summer internships outside of my field of research to broaden my understand and challenge my interest in nuclear science.

The summer prior to my senior year, I accepted an offer to conduct research at the Massachusetts Institute of Technology through an interdisciplinary Research Experience for Undergraduates in the Center for Materials Science and Engineering. Unique to this program, our cohort was offered twenty-two research presentations and lab tours from MIT faculty conducting materials science research, allowing us to see the vast scope and applicability of materials science projects across disciplines. Motivated by his hands-on mentorship style, I chose to work under Dr. Yuriy Román-Leshkov in the Chemical Engineering department, creating transition metal carbide nanoparticles coated in an atomically thin platinum layer by reverse microemulsion-mediated synthesis. The synthesized nanoparticles catalyze hydrogen evolution reactions as effectively as pure platinum metal nanoparticles, but resist carbon monoxide poisoning to the catalyst. I explored adjustments to the existing nanoparticle architecture, and the resultant influence on the nanoparticles' catalytic properties. Through this program, I was involved in a project with strong ties to chemical industry that addressed immediate, pressing concerns in the future of petroleum technology; however, I felt that analyzing these problems from the perspective of an engineer overlooked the chemical fundamentals in favor of this practicality.

Resultant to my experiences, I have chosen to pursue a Ph.D. in Inorganic Chemistry. Bridging the synthetic inorganic chemistry experiences of my undergraduate research and catalysis research experiences from my summer internship, I have chosen to study novel inorganic clusters modeling catalysts found in biological systems for small molecule activation. The ultimate goal of this research is reducing energy barriers and increasing efficiency for global energy processes, including nitrogen fixation and carbon dioxide reduction, to promote global

energy independence from non-sustainable resources. In this research, I have certainty that my independent efforts will contribute to this cause over the duration of my degree and beyond.

With the support and network provided by the Hertz Foundation, I can fully exhaust my potential to act as a catalyst for change at the interface of academia and industry.

Question 3: Choice of Graduate School

What are the considerations involved in your choice of graduate school?

I chose to attend the California Institute of Technology because the campus has a pervasive sense of humility and opportunity that I believed would best support my development as a research scientist and inspire the creativity of my research.

As a research scientist in-training, I thirsted for an environment that was saturated with students from all walks of life, and a community that was never short of intellectual potential. Attending my first day of classes at Caltech, it dawned on me that every person I encounter is uniquely exceptional. Each day I come to campus, I know that the student population around me is an extraordinarily hardworking and intelligent community, comprised of the world's future leaders in science across all disciplines. But beyond that, I am constantly mystified at the diversity of experience and breadth of culture all concentrated at one institution.

There is an inherently comfortable, collaborative culture that strongly ties the student community, in academics and beyond. When matriculating, graduate students are encouraged not to feel parameterized by their planned field of study and explore options of study outside of their own. Faculty office doors remain open, constantly encouraging communication and critical discussion with your instructors. Conferences and seminars are a daily activity, meaning that there is a constant stream of new encounters and networks being made available to you. Coursework strongly and genuinely encourages student collaboration on all assignments, with an emphasis placed on sharing knowledge interpersonally in addition to attending lecture.

Finally, I chose Caltech because this school is nothing like my home. As a first-generation college student, I am constantly reminded in my experience that my parents never had the opportunity to study at an institution of this caliber, or the flexibility to decide to move across the country to pursue their dream. I sought a graduate institution that would challenge my ideas and regularly push me outside of my comfort zone. Even outside of campus, there is so much inspiration in the heterogeneity of the Los Angeles area. Every time I walk outside between classes and see the mountains to the north of campus, I am reminded that attending this institution is the goal I had been working toward my entire life.

Question 4: Chronological Resume

Provide a concise resume, in chronological order, with dates, recapitulating significant periods of **technical and other creative activity** since high school graduation. Omit activities only distantly related to your professional development. Include workshops, summer schools, a general description of all courses of study pursued (e.g. "3 quarters of Differential Equations") and degrees expected or awarded (dates, institutions, fields). Separate your undergraduate activities from your graduate activities (if/as applicable) with a single dashed line.

FALL 2013
- Honors General Chemistry I with Laboratory (4 credits)
- Calculus I (4 credits)

SPRING 2014
- Honors General Chemistry II (3 credits)
- Honors-augmented Honors General Chemistry I – Conducted undergraduate research for academic credit as an alternative to lab coursework. (2 credits)
- General Physics A with Laboratory (5 credits)
- Calculus II (4 credits)

SUMMER 2014
- Calculus III (5 credits)
- General Physics B with Laboratory (5 credits)

FALL 2014
- Honors Organic Chemistry I (3 credits)
- Analytical Chemistry with Laboratory (4 credits) – Course on chemical instrumentation and analytical procedure.
- Directed Individual Study Research (1 credit) – Began undergraduate research project under Dr. Thomas Albrecht-Schmitt.
- General Genetics (3 credits) – Enrolled in course to complete Biology minor, coupled with AP Biology credit.
- Intro to Scientific Computing – Enrolled in a course applying Java coding to problems in math and science, out of leisure and curiosity.
- National Aeronautics and Space Administration Virtual Internship – Began virtual internship providing technical support to the Office of Human Capital Management.

SPRING 2015
- Organic Chemistry II (3 credits)
- Chemistry of Materials (3 credits) – Elective upper-division and graduate mixed course, which covers the fundamentals of experimental chemistry methods.
- Honors Directed Individual Study Research (3 credits) – Continuing research project.
- Ordinary Differential Equations (3 credits) – Enrolled in course out of interest.
- Programming I (3 credits) – Enrolled in course out of interest.

SUMMER 2015
- General Biochemistry I (3 credits) – Course completed for degree certification.

- Organic Chemistry Lab (3 credits)

FALL 2015
- Physical Chemistry I with Laboratory (4 credits) – Thermodynamics for chemists.
- Honors Work (2 credits) – Continuing undergraduate research project.
- Symbolic and Numerical Computations (3 credits) – Course covers mathematical derivations of computational algorithms. Learned and applied Matlab.

SPRING 2016
- Physical Chemistry II with Laboratory (5 credits) – Quantum mechanics for chemists.
- Advanced Analytical Chemistry (3 credits) – Course covering chemical instrumentation and data analysis.
- Honors Work (3 credits) – Continuing undergraduate research project.
- Algorithms for Science Applications I – Matlab course focused on algorithms with applications in science and engineering.

SUMMER 2016
Research Experience for Undergraduates – MIT Center for Materials Science and Engineering

FALL 2016
- Quantum Mechanics (Graduate, 3 credits) – Enrolled in graduate course out of personal interest.
- Inorganic Chemistry (3 credits) – Course covers the fundamentals of metal-based chemistry.
- Advanced Analytical Chemistry Lab (1 credit) – Hardest course of my degree. Laboratory instrumentation course with high standards of performance. Received grade in the course.
- Data Mining (Graduate, 3 credits) – Fundamentals and practical applications of machine learning.
- Honors Work (3 credits) – Continuing undergraduate research project.

Spring 2017
- Inorganic Chemistry Laboratory (1 credit) – Laboratory course covering metal chemistry,
- Principles of Inorganic Chemistry (Graduate, 3 credits) – Course continues covering the fundamentals of metal-based chemistry.
- Bio-Nanomaterials (Graduate, 3 credits) – Course covers physical chemistry analysis for polymeric and nanoparticle systems.

FALL 2017
- Structure Determination by X-Ray Crystallography (9 units)
- Inorganic Chemistry (9 units)
- Introduction to Electrochemistry (9 units)

Academic Honors

In the space provided below, list, in chronological order, academic honors and distinctions which you have received and the time or time-interval of receipt. Separate your undergraduate from your graduate awards (if/as applicable) with a single dashed line (Include title, reason for award, and where/when received). Especially significant awards received in high school can also be included. Use no more than one line per award whenever possible (what, where/when received). *You may use more than the allotted space for your response, and any additional text will be included in your application.*

Florida State University Freshman Scholarship – Awarded $9600 Florida State University institutional scholarship based on high school merit (August 2013).
* Phi Eta Sigma Honor Society membership - Awarded membership to national honor society (March 2014).
* Phi Beta Kappa Honor Society – Awarded membership to national honor society as an academic junior with 3.9 GPA (October 2014).
Russell H. and Dorothy P. Johnsen Scholarship – Awarded $2000 Florida State University Chemistry departmental scholarship, selected on academic merit and research experience (April 2015).
Goldwater Scholarship – Selected Florida State University Goldwater scholarship nominee based on research proposal and personal statement (January 2016).
Scholarship Award – Garnet and Gold Key Leadership Honorary – Nominated and selected by peer leaders for academic accomplishment (March 2016).
The Charles A. and Louise I. Brautlecht Scholarship in Chemistry – Awarded $2000 Florida State University Chemistry Departmental scholarship, selected on academic merit and research experience (April 2016).
*Department of Energy Integrated University Program Scholarship Awarded $7500 for undergraduate research in nuclear science. Award selected based on research merit, reference letters, and personal statement. (FY 2015-2016).
* MIT Center for Materials Science and Engineering Research Experience for Undergraduates – One of twelve students admitted to competitive interdisciplinary summer research internship. Study in nanoparticle synthesis and catalysts for hydrogen evolution reactions under Dr. Yuriy Roman- Leshkov (Summer 2016).
*Department of Energy Integrated University Program Scholarship- Awarded $7500 for undergraduate research in nuclear science. Award selected based on research merit, reference letters, and personal statement. (FY 2016-2017).

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Institutional Research Fellowship - California Institute of Technology Department of Chemistry and Chemical Engineering – Funding to support research endeavors in the first academic year of graduate study (2017-2018)

Fellowships, Scholarships, etc.

Florida State University Freshman Scholarship – Awarded $9600 Florida State University institutional scholarship based on high school merit (August 2013).
* Phi Eta Sigma Honor Society membership - Awarded membership to national honor society (March 2014).
Florida State University Student Government: Undergraduate Studies Seat Sixteen – Elected student leader in Florida State University Student Government Association, representing predivisional undergraduate students (March 2014).
Seminole Torchbearers Recognition – Leadership recognition conferred by the Florida State University Division of Student Affairs (October 2014).
Garnet and Gold Key Leadership Honorary – Awarded membership to Florida State University's oldest honor society, with tenants of leadership, service, spirit, and scholarship (October 2014).
* Phi Beta Kappa Honor Society – Awarded membership to national honor society as an academic junior with 3.9 GPA (October 2014).
Florida State University Student Government: Student Senator of the Year – Nominated and elected award by over sixty cohort student-leaders in the Florida State University Student Senate (March 2015).
National Aeronautics and Space Administration – Virtual Student Foreign Service – Virtual internship with the NASA Office of Human Capital Management, coordinating internal and public virtual meetings with NASA staff and leadership (September 2014 – April 2015).
Russell H. and Dorothy P. Johnsen Scholarship – Awarded $2000 Florida State University Chemistry departmental scholarship, selected on academic merit and research experience (April 2015).
College Leadership Florida, Class XVII – Membership in Leadership Florida, a statewide network and community of leaders working for a better Florida (August 2015).
Goldwater Scholarship – Selected Florida State University Goldwater scholarship nominee based on research proposal and personal statement (January 2016).
Scholarship Award – Garnet and Gold Key Leadership Honorary – Nominated and selected by peer leaders for academic accomplishment (March 2016).
The Charles A. and Louise I. Brautlecht Scholarship in Chemistry – Awarded $2000 Florida State University Chemistry Departmental scholarship, selected on academic merit and research experience (April 2016).
*Department of Energy Integrated University Program Scholarship- Awarded $7500 for undergraduate research in nuclear science. Award selected based on research merit, reference letters, and personal statement. (FY 2015-2016).
* MIT Center for Materials Science and Engineering Research Experience for Undergraduates – One of twelve students admitted to competitive interdisciplinary summer research internship. Study in nanoparticle synthesis and catalysts for hydrogen evolution reactions under Dr. Yuriy Roman- Leshkov (Summer 2016).
*Department of Energy Integrated University Program Scholarship- Awarded $7500 for undergraduate research in nuclear science. Award selected based on research merit, reference letters, and personal statement. (FY 2016-2017).
Tutorial Assistant – Florida State University Center for Retention and Academic Enhancement - Mathematics and science tutor for students enrolled in the FSU CARE Program, which provides transition, engagement, and academic support services for traditionally underrepresented and

disadvantaged populations at Florida State University (Summer 2015- Spring 2017).
Undergraduate Teaching Assistant for Organic II Laboratory (CHM 2211L) – Florida State University Department of Chemistry - Teaching assistant for a three credit-hour upper-division course. Instruct, grade, and advise for one section containing sixteen students (Fall 2016, Spring 2017).

Institutional Research Fellowship - California Institute of Technology Department of Chemistry and Chemical Engineering – Funding to support research endeavors in the first academic year of graduate study (2017-2018).

Previous Research

B.S. Researches Pursued
3
B.S. Researches Documented
3
B.S. Researches Submitted to Refereed Publications
1

Grad. Researches Pursued
1
Grad. Researches Documented
0
Grad. Researches Submitted to Refereed Publications
0

Previous Research

1) "Quantification of Mn2+ in a Mn-doped Dimethylammonium Zinc Formate Framework." (January 2014 – April 2014)

ORAL PRESENTATION:

Barth, A. T.; Abhyankar, N; Dalal, N. S., (2014, April). Quantification of Mn2+ in a Mn-doped Dimethylammonium Zinc Formate Framework. Delivered at Florida State University, CHM 1051L Course Recitation.

POSTER PRESENTATION:

Barth, A. T.; Abhyankar, N; Dalal, N. S. "Quantification of Mn2+ in a Mn-doped Dimethylammonium Zinc Formate Framework." April 2014. Florida State University, Department of Chemistry and Biochemistry, CHM 1051L Honors General Chemistry II Laboratory Research Poster Session, Tallahassee, Florida.

2) "Hydrothermal Synthesis of Lanthanide Series Plumbites." (May 2014 – December 2016)

PUBLICATION

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Beatrice, M. T.; Silver, M. A.; Cary, S. K.; Eaton, T. M.; Albrecht-Schmitt, T. E., "Hexanuclear and Pentanuclear Lanthanide Plumbite Nanoclusters." (In Preparation)

ORAL PRESENTATIONS:

Barth, A. T.; Stritzinger, J. T.; Albrecht-Schmitt, T. E., (2015, November). Synthesis and Study of Lanthanide Series Plumbites. Delivered at Florida State University, American Chemical Society General Body Meeting.

Barth, A. T.; Stritzinger, J. T.; Albrecht-Schmitt, T. E., (2015, March). Synthesis and Study of Lanthanide Series Plumbites. Delivered at Florida State University, Undergraduate Research Showcase.

POSTER PRESENTATIONS:

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." January 2017. Harvard University, National Collegiate Research Conference, Cambridge, Massachusetts.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." March 2016. Florida State University, FSU Center for Research and Creative Endeavors, FSU Undergraduate Research Symposium 2016, Tampa, Florida.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." February 2016. University of Tampa, Florida Undergraduate Research Conference 2016, Tampa, Florida.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." May 2015. Florida State University, Department of Chemistry and Biochemistry, 2015 North American Solid State Chemistry Conference, Tallahassee, Florida.

Barth, A. T.; Stritzinger, J. T.; Pace, K. P.; Silver, M. A.; Albrecht-Schmitt, T. E., "Hydrothermal Synthesis of Lanthanide Series Plumbites." May 2015. American Chemical Society Florida Section, Florida Annual Meeting and Exposition, Tampa, Florida.

3) "Transition Metal Carbide Nanoparticles Coated with Noble Metal Monlayers for CO-Tolerant Catalysis." (June 2016 – August 2017)

POSTER PRESENTATION:

Barth, A. T.; Milina, M.; Román-Leshkov, Y. "Transition Metal Carbide Nanoparticles Coated with Noble Metal Monlayers for CO-Tolerant Catalysis." August 2016. Massachusetts Institute of Technology, Center for Materials Science and Engineering, The CMSE/MPC Summer Research Internship Program Poster Session, Cambridge, Massachusetts.

4) “Modeling the Nitrogenase FeMo Cofactor with Tunable Multimetallic Clusters.” (October 2017 to present)

***** IMPORTANT*****
Finally, choose one or two projects that best exemplify your own creativity and discuss in more detail what you personally contributed to them.

Note that compelling example(s) of personal creativity are a very important factor in our selection process. Please highlight what makes your personal contributions stand out, and use the first person wherever appropriate. Specific evidence of your personal creativity is more important to us than what your research group did as a whole, unless you contributed centrally to its leadership.

Please submit copies of your most significant scientific publications/reports using the upload button on the Supplemental & Other Information page of this application.

The research experience that inspired and broadened my perspective the most was my summer experience interning in a chemical engineering laboratory. In retrospect, this experience was a summer of reciprocal gain, as I intellectually challenged the protocol and methodologies assumed by my research group, and they responded in kind. From a chemistry perspective, conducting research means being astutely observant of the slightest nuances in a reaction that could completely throw your equilibrium and render your experiment useless. Exploratory research is usually performed conservatively on the milligram scale, and products are handled carefully as through valuable at all times. In stark contrast, the chemical engineering research in my laboratory was a research of haphazard and extremes relative to my previous experiences. Exploratory research was conducted on a gram scale or in huge multi-liter apparatuses. Solvents were purchased in bulk and consumed in a week, and most days were spend listening to the harsh clanging of two wrenches together as gas tanks were exchanged.

During the summer, I was enlisted to work on a ninety-step reverse microemulsion-mediated synthesis project. In my project, I frequently realized inefficiencies in the procedure, and proposed methods of reforming and expediting the research while preserving integrity of the data. After brainstorming project ideas with another graduate student, I suggested that he change his experiment parameters to attain the thermodynamic versus kinetic intermediate, which entirely shifted the direction of his thinking while approaching the problem. Additionally, I ran electrochemical experiments for the first time as a method of evaluating the effectiveness of researched catalysts; after weeks of tribulation, I troubleshoot evaluated the instrumentation and independently reconfigured the setup to remedy the circuitry issues. Through this experience, I learned to appreciate the differing experimental lens of my cohort, and through mutual discussion of our differing perspectives, we can both intellectually benefit.

Were you a Goldwater Scholar or Nominee? Nominee

Personal Essay
This page is to be used for submitting a personal essay or for pasting in an essay that is TEXT only. Include here information about your favored extracurricular and leisure time activities since your graduation from high school. **You may use more than the allotted space for your response, and any additional text will be included in your application.**

During my undergraduate degree, I was intimately involved in the operation and management of a Student Government political party. Titled "The Ignite Party," and symbolized by a simple flame on a paprika-red backdrop, I was introduced to this organization early through my involvement in a freshman leadership program at Florida State University. The political party system enabled students to band together as a united front during Student Government elections in the Fall and Spring terms, selecting qualified candidates to run for student-leadership office, and bear the elected responsibility of allocating and spending the $13.7 million university Activities and Services Fee budget. I sought a sense of community when matriculating to a school of over 40,000, and found many of the most distinguished student-leaders shared this same affiliation.

My early involvement in Student Government led to holding an executive board position within the Ignite Party and committee leadership position in Student Senate by my sophomore year. My involvement and leadership soon involved controversy when articles for impeachment were filed against the elected Student Body President during my sophomore year, and I was responsible for the judicial committee to investigate the claims and determine his culpability. I was thorough in investigating all evidence under record and respectfully refused all discussion off record until the process was complete. Despite the contention this period brought about, I constantly took a seat at the table, interjected, and mediated discussion when tensions arose.

In the following Spring, a conflicting faction of The Ignite Party developed into an opposing political party and challenged our election slate. Campaigning activities followed strict guidelines to maintain public decorum and noninterference with academia, and if a violation was reported, student party leaders were responsible for litigating their case before third-year law students to avoid monetary fines or party disqualification. During this process, I was constantly requested as the primary litigator on behalf of my party, and if busy, I framed the argument against each violation and coached my cohort leaders in the unpacking and negation of each claim made against us. I frequently argued cases submitted by law students and won as an undergraduate sophomore with no prior oratory or debate experience.

My favorite part about involvement in this organization was the opportunity to recognize potential student leaders in their freshman year, mentor and inspire these students, and see how they develop throughout their undergraduate career and beyond. Although my intentions with this party were always in good faith, I experienced moral difficulties as the party began to develop into something I could no longer recognize or believe in. The most difficult decision of my undergraduate involvement was making the announcement to dissociate from this organization and abandon many of my invested experiences in the process. In retrospect, my impassioned involvement with this organization helped me realize the boundlessness of my capability, shaping my self-confidence and developing leadership skills through application. These experiences challenged my ability to improvise in the face of adversity, creatively tackle and solve problems, and respectfully communicate disagreement and controversy with others. These qualities are congruent with my personality and passions, and because of these experiences, I have grown into a much more spontaneous, intentional, and imaginative scientist and researcher.